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OBSERVATIONS ON THE INFLUENCE OF AN ELECTRO-MAGNET ON SOME OF THE PHENOMENA OF A NERVE. By Professor M'Kendrick, *University of Glasgow.*

1. Whilst observing the phenomena produced by the influence of a magnet on the electric discharge in gases, it occurred to me to examine the actions of a living nerve in a magnetic field. As I had no powerful permanent magnet in my possession, I employed a horse-shoe electro-magnet of soft iron, each limb being 7 inches in length, and the diameter of the bar $1\frac{1}{4}$ inches. The battery employed consisted of twenty of Sir William Thomson's tray-cells, united in "multiple arcs" of ten. A key was interposed in the circuit so as to make and break the current of the electro-magnet at pleasure. On the poles of the electro-magnet, I placed two flat rectangular pieces of soft iron, each $2\frac{1}{2}$ inches long by $1\frac{1}{4}$ inches broad. By moving these pieces on the poles, whilst the core was unmagnetized, the extent of the magnetic field could be varied at pleasure. The magnet and other portions of the apparatus were insulated by glass plates, and the wires leading the current from the battery to the magnet were thick copper wires insulated by gutta-percha.

2. Having prepared the limb of a frog in the method usually followed in physiological experiments, the sciatic nerve was stretched from the one pole of the electro-magnet to the other, touching both. It was then found that, on closing the key in the circuit of the electro-magnet, there was sometimes a contraction of the limb, and that there was usually a contraction on opening the key,—at all events, whilst the nerve retained its irritability, there was contraction either in closing or on opening the current. This happened when the nerve was touching the poles of the electro-magnet, and it might be supposed that it was due in some way to an escape of a portion of the current through the nerve. To test this, I connected each of the poles of the electro-magnet (the flat plates above referred to) with a very sensitive reflecting galvanometer standing at a distance of 12 feet from the electro-magnet, and found that, when the current

of the electro-magnet was closed and opened, there was a deviation of 3 degrees (and the galvanometer was so sensitive that merely touching the terminals drove the spot of light off the scale). Consequently, the current passing into the galvanometer circuit was extremely small. To ascertain whether the galvanometer current might not be due to an inductive effect of the electro-magnet, I laid a bit of copper wire from the one pole of the electro-magnet to the other, so as to complete the galvanometer circuit, and then it was ascertained that there was the same amount of deviation of the needle on opening and closing the circuit of the electro-magnet. Thus, it would seem that on opening and closing the circuit of the electro-magnet, a nerve resting on its poles is irritated, and a sensitive galvanometer connected with its poles is also very slightly affected. Both of these effects are probably due to an induction current developed instantaneously in the nerve and in the galvanometer circuit at the moment of opening and of closing the circuit of the electro-magnet.[1]

In these experiments, the nerve, as above stated, was so placed as to touch the moveable flat plates on the poles of the electro-magnet. Contractions were also obtained when the nerve was laid on the naked poles of the electro-magnet, and even when it was placed *on one pole.* In the latter instances the electro-magnet evidently directly stimulated the nerve, probably by exciting in it a brief induction current.

3. In another series of experiments, a freshly prepared nerve was laid on the poles, so that about 1 inch of nerve stretched from pole to pole. By means of the key in the circuit of the electro-magnet, the latter could be made magnetic and non-magnetic at pleasure. With the view of ascertaining whether the excitability of the nerve was in any way affected by its position between the magnetic poles, I touched it with a copper wire whilst the key was open, and consequently the electro-magnet was not acting, and immediately there were contractions of the limb; on closing the key so as to form the electro-magnet, the same stimulation produced no effect. This observation was made many times, and the conclusion first arrived at was that

[1] Clerk Maxwell, *Electricity and Magnetism*, vol. ii. p. 180.

the magnetic influence diminished the irritability of the nerve. To check this theory, several test experiments were made. Every part of the apparatus was carefully insulated, and the operator stood on a stool having glass legs. When he touched the nerve with the copper wire, it was then found that no contractions took place either whilst the electro-magnet was magnetic, or whilst it was not. But when the operator placed his hand on the table, and touched the nerve with the wire, contractions again took place. To vary the observation, the key in the electro-magnetic circuit was left open, and an assistant was sent to the battery, about ten yards off, but in the same apartment, and he was told to make and break at the battery, on the word of command. It was found that when the current was closed at the battery, the operator, standing on the floor, could excite the nerve by a copper wire, but when he stood on a stool with glass legs, he could not do so. When the current was opened at the battery, the operator could still influence the nerve two or three times, whilst standing on the floor, and then the influence passed off. The inference, therefore, was that a branch current passed from the battery through the floor and through the body of the operator, and that this current irritated the nerve. When, however, the current of the battery was sent through the electro-magnet, irritation of the nerve by the copper wire produced no effect. Possibly one or both of two events followed the forming of the current of the electro-magnet:—(1.) The branch current just alluded to may have disappeared or been very much weakened; and (2) the current derived from the poles of the electro-magnet, the effects of which I have described in the second paragraph of this paper, may have had some influence on the irritability of the nerve. After many attempts, however, I have not been able to detect the existence of the supposed derived current except my means of the nerve *in the presence of the electro-magnet.* If I removed the nerve from the poles of the electro-magnet, and placed it in a similar position over the two rectangular pieces of soft iron above mentioned, the two pieces resting on a granite block, touching the nerve with the copper wire produces no effect. Again, if a feeble continuous current passed from one pole of the electro-magnet, through the nerve to the other, the effect ought to be, in accordance with the law of

electrotonus, increase of excitability (katelectrotonus) instead of its diminution. As, however, the nerve became less excitable during the action of the electro-magnet, the effect could not be owing to the passage of a feeble current through the nerve, from pole to pole of the electro-magnet.

But another explanation might be offered of these results. There could be no doubt that a branch current found its way from the floor, through the body of the operator, inasmuch as when the nerve was touched with a copper wire, vigorous contractions took place, whereas, when the body of the operator was insulated, no such effect was produced. These phenomena were observed when the key of the circuit of the electro-magnet was open, and they disappeared when the key was shut; that is, they took place only when the current did not flow through the coil of the electro-magnet. Hence, it might be supposed that the current could pass more readily through the coil of the electro-magnet, than through the floor and the operator. The difficulty attending this explanation is that, when the nerve was laid on the metal plates, at a distance, say 8 or 10 inches, from the electro-magnet, touching it with the copper wire, either whilst the electro-magnetic circuit was open or shut, caused no contractions. The phenomena only occurred when the nerve lay on the naked poles of the electro-magnet, or on the flat plates placed on these poles, and the inference, therefore, is that the presence of the electro-magnet was necessary. It would therefore appear that *a portion of nerve stretched between the poles of an electro-magnet, so as to touch each, will not excite contractions in a muscle when touched by a copper wire during the passage of the current through the wire of the electro-magnet.*

4. In the preceding experiments, the nerve actually touched the poles of the electro-magnet. In other experiments, the nerve was laid on a thin glass plate, placed between the flat iron plates before described, but without touching either plate, and it was so arranged that it lay at right angles to a line joining the two magnetic poles. Thus, the nerve fibres would conduct in a direction at right angles to the magnetic lines of force. No satisfactory results were obtained, but enough was observed to show that the nerve was affected. Occasionally the muscle contracted.

I intend continuing these researches with the aid of a powerful electro-magnet in the Physical Laboratory of the University of Glasgow. It appears to be highly probable that nervous activity may be affected by magnetic action, and the experimental problem is to ascertain the conditions in which this may be done. At present, I merely state the facts observed, without entering upon a discussion of how they may be interpreted.